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ETCHED INTERCONNECT FOR FUEL CELL ELEMENTS

TECHNICAL FIELD

The present invention relates to fuel cells and is particularly related to etched interconnect devices for planar solid oxide fuel cells and with a method for preparing such interconnect devices.

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application claims priority to U.S. Provisional Application Serial No. 60/201,569 (Attorney Docket No. DP-302846) entitled "Etched Interconnect for Fuel Cell Elements," which is hereby incorporated by reference herein in its entirety.

BACKGROUND OF THE INVENTION

Fuel cells are electrochemical devices that convert chemical potential energy into usable electricity and heat without combustion as an intermediate step. Fuel cells are similar to batteries in that both produce a DC current by using an electrochemical process. Two electrodes, an anode and a cathode, are separated by an electrolyte. Like batteries, fuel cells are combined into groups, called stacks, to obtain a usable voltage and power output. Unlike batteries, however, fuel cells do not release energy stored in the cell, running down when battery energy is gone. Instead, they convert the energy typically in a hydrogen-rich fuel directly into electricity and operate as long as they are supplied with fuel and oxidant. Fuel cells emit almost none of the sulfur and nitrogen compounds released by conventional combustion of gasoline or diesel fuel, and can utilize a wide variety of fuels including natural gas, coal-derived gas, landfill gas, biogas, alcohols, gasoline, and diesel fuel oil.

Several types of fuel cells are under development. Among these, the solid oxide fuel cell (SOFC) is regarded as the most efficient and versatile

power generation system, particularly for dispersed power generation, providing low pollution, high efficiency, high power density and fuel flexibility. In transportation applications, SOFC power generation systems are expected to provide a higher level of efficiency than conventional power generators which employ heat engines such as gas turbines and diesel engines that are subject to Carnot cycle efficiency limits. Therefore, use of SOFC systems as power generators in vehicle applications is expected to contribute to efficient utilization of resources and to a relative decrease in the level of CO_2 emissions and an extremely low level of NO_x emissions. SOFC systems designed to address specific concerns and requirements of operation in a vehicle are under development including SOFC systems designed to serve as an auxiliary on-board power unit rather than as the prime energy source of the vehicle.

As with fuel cells generally, very hot solid oxide fuel cells (SOFC) having high electrical conductivity, are used to convert chemical potential energy in reactant gases into electrical energy. In the SOFC, two porous electrodes (anode and cathode) are bonded to an oxide ceramic electrolyte (typically, yttria stabilized zirconia, ZrO_2-Y_2O_3) disposed between them to form a selectively ionic permeable barrier. Molecular reactants cannot pass through the barrier, but oxygen ions (O^{2-}) diffuse through the solid oxide lattice. The electrodes are typically formed of electrically conductive metallic or semiconducting ceramic powders, plates or sheets that are porous to fuel and oxygen molecules. Manifolds are employed to supply fuel (typically hydrogen, carbon monoxide, or simple hydrocarbon) to the anode and oxygen-containing gas to the cathode. The fuel at the anode catalyst/electrolyte interface forms cations that react with oxygen ions diffusing through the solid oxide electrolyte to the anode. The oxygen-containing gas (typically air) supplied to the cathode layer converts oxygen molecules into oxygen ions at the cathode/electrolyte interface. The oxygen ions formed at the cathode diffuse, combining with the cations to generate a usable electric current and a reaction product that must be removed from the cell (i.e., fuel cell waste stream) or recycled such as with a waste energy recovery device.

Individual fuel cells are stacked anode to cathode, to provide a fuel cell stack providing the desired output voltage. Conductive, typically metal, plates referred to as interconnects are interleaved between each fuel cell, as well as at each end of a fuel cell stack and at each side of a single fuel cell. One function of the interconnect is to convey electrical current away from the fuel cell and/or between adjacent fuel cells and heat away from the fuel cell or cells. The interconnect, therefore, should have a relatively high electrical conductivity to minimize voltage losses, with negligible contact resistance at the interconnect-electrode interface. The interconnect should further have a relatively high thermal conductivity to provide uniformity of heat distribution and to reduce thermal stresses. A thermal conductivity above about 25 W/m K, for example, is desirable. Since an intermediate interconnect in a fuel cell stack extends between the anode of one fuel cell and the cathode of the adjacent fuel cell, the interconnect must be impervious to gases in order to avoid mixing of the fuel and oxidant. Thus, the interconnect should have a relatively high density with no open porosity, as well as stability in both oxidizing and reducing environments at the operating temperature. The interconnect should further have high creep resistance so that there is negligible creep at the operating temperature and a low vapor pressure. The interconnect should further exhibit phase stability during thermal cycling, have a low thermal expansion mismatch between cell components, and have chemical stability with respect to components with which it is in contact. The interconnect should possess sufficient strength to provide structural support to the relatively fragile fuel cells. In addition, the interconnect should preferably be low cost, easily fabricated, and have low brittleness.

A second function of the interconnect is to provide gas flow passages on the top and bottom surfaces while maintaining good electrical contact to the fuel cell. The gas flow passages are preferably configured to minimize flow pressure drop of the gas streams while promoting swirl or mixing for good fuel utilization (anode) and heat transfer (cathode). The gas

flow passages are connected to supply and return manifolds which can be discrete devices or integral to the interconnects and fuel cells.

Ceramic, cermet and alloy interconnects are known in the art. Metallic materials have the advantages generally of high electrical and thermal conductivity and ease of fabrication. However, stability in a fuel cell environment comprising high temperatures in both reducing and oxidizing atmospheres, limits the number of available metals that can be used in interconnects. Most high temperature oxidation resistant alloys have some kind of built-in protection mechanism, typically forming oxidation resistant surface layers. Fabrication of such interconnects is complex and may comprise, for example, providing three sheet metal sheets having appropriate gas flow channels formed therein and combining the sheets, such as by brazing, to form an interconnect assembly having anode gas (fuel) channels on one side, cathode gas (oxidant, typically air) channels on the opposite side, and integral anode gas supply channels. A support for the ceramic fuel cell is provided on the anode side, such as a sheet of nickel foam, which foam support provides flow passages for the anode gas and electrical connection from the cell to the interconnect. The anode gas supply channels must be sealed from one interconnect to the next, such as with a non-conducting gasket.

What is needed in the art is a simplified, lower cost, high efficiency interconnect for fuel cell elements.

SUMMARY OF THE INVENTION

An etched interconnect for fuel cell elements comprising solid oxide electrolyte, an anode, and a cathode, includes a single conductive base sheet having first and second major faces on opposite sides of the base sheet, anode gas flow passages disposed on the first face of the base sheet and cathode gas flow passages disposed on the second face of the base sheet. The anode gas flow passages and cathode gas flow passages have a geometry selected to optimize fuel and oxidant gas flow according to system requirements.

In a preferred embodiment, the anode gas flow passages comprise a large quantity of small diameter, closely spaced contact points. In another preferred embodiment, the cathode gas flow passages are configured to provide deep flow passages to promote oxidant mixing and a large surface area for optimum heat transfer to the cathode gas stream.

A method for preparing the etched interconnect includes preparing anode gas passages and cathode gas passages on first and second faces, respectively, of the single conductive base sheet, selecting the geometry of the anode and cathode gas flow passages so as to optimize fuel and oxidant gas flow according to system requirements. Preparing may comprise any means sufficient to cut the desired gas passage geometry into the base sheet. In a preferred embodiment, the gas flow passages are prepared using a photochemical etching process.

Advantageously, the present etched interconnect is thinner and structurally stiffer than prior comparable interconnect devices. The present method further enables fine, intricately etched gas passage configurations providing optimum flow characteristics. The simplified interconnect provides ease of manufacture and therefore lower cost compared to previous devices. In addition, the closely spaced un-etched contact points that contact the ceramic fuel cell surface provide structural support to the cell to prevent fracture of the ceramic cell.

These and other features and advantages of the invention will be more fully understood from the following description of certain specific embodiments of the invention taken together with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Referring now to the drawings, which are meant to be exemplary, not limiting, and wherein like elements are numbered alike in the several Figures:

FIG. 1 is a perspective view of an anode side of an etched interconnect in accordance with one possible embodiment of the present invention.

FIG. 2 is a view showing further detail of a portion of the etched interconnect of FIG. 1.

FIG. 3 is a perspective view of a cathode side of an etched interconnect in accordance with one possible embodiment of the present invention.

FIG. 4 is a view showing further detail of a portion of the etched interconnect of FIG. 3.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Turning to FIG. 1, the anode side of an etched interconnect 10 in accordance with one possible embodiment of the present invention is shown. The etched fuel cell interconnect 10 includes a base sheet comprising a single piece of sheet metal 12 having anode and cathode gas flow passages disposed on opposite sides thereon. The first face 14 of the base metal sheet 12 has anode gas flow passages 16 and standing surfaces 18. A second face 20 has cathode gas flow passages 22 and standing surfaces 18 (cathode side shown in FIGS. 3 and 4).

The base metal sheet 12 may comprise any material having sufficient conductivity and strength characteristics. Preferably, the base metal sheet 12 is selected to match the thermal expansion co-efficient of the fuel cell element. Examples of materials suitable for the base metal sheet 12 include, but are not limited to, stainless steel, high temperature alloys, nickel alloys, and combinations thereof.

One aspect of the present invention comprises preparing anode gas flow passages on a first face of the conductive base sheet and preparing cathode gas flow passages on the second face, selecting the gas flow passage geometry on each face so as to optimize fuel and oxidant gas flow in accordance with the particular system requirements. Any suitable process may

be employed to prepare the etched interconnect providing that the selected process enables disposition of different geometric configurations on the anode and cathode faces of the interconnect. For example, flow passage depth and pattern intricacy may be selected for each side, anode and cathode, providing optimum flow channel geometry for the different flow requirements. Even after processing, the overall interconnect geometry remains flat, stiff, and of a substantially uniform thickness, providing enhanced structural support to the fuel cell (not shown). Suitable processes include, but are not limited to, etching processes such as photochemical and electrochemical etching, and cutting, such as with a laser or other suitable device, among others.

In one preferred aspect of the present invention, the interconnect 10 is prepared using a photochemical metal machining process. Such processes comprise generally coating the subject to be machined with photosensitive material (photoresist), registering a mask on the coated subject, typically on both sides, and exposing and developing the photoresist. The process further comprises etching the metal subject by exposing to acid, the exposed photoresist protecting the areas on the subject that are to remain un-etched. After etching, the remaining photoresist is removed, leaving the etched passages and un-etched points that were protected by the photoresist. One feature of this process is that different patterns can be etched on the two sides of the subject plate, and that each side can be etched to a different depth depending on the pressure of the acid jets and their placement.

FIG. 2 provides a close-up view of a portion of the anode side of the etched fuel cell interconnect 10 shown in FIG. 1. The standing (that is, un-etched) surfaces 18 have flat faces which provide good electrical contact to the fuel cell. Large portions of the standing surfaces 18 are co-planar thus providing good mechanical support to the fuel cell element.

FIGS. 1 and 2 provide a highly simplified schematic view of the etched anode gas flow passages 16. The geometry of the gas flow passages can be extremely detailed with fine features for optimizing anode gas flow, or features that vary across the interconnect to compensate for fuel gas

concentration changes and temperature changes of the anode gas as it flows across the fuel cell.

In a preferred embodiment, the anode gas flow passages 16 and cathode gas flow passages 22 (best shown in FIG. 4) are each configured with a distinct pattern and depth selected to optimize fuel and oxidant gas flow according to the particular system requirements. In a most preferred embodiment, the anode face 14 comprises a large quantity of small diameter, closely spaced contact points 18. For example, in one embodiment of the present invention, the contact points may be present on the anode face 14 at a density of about 10 to about 25 contact points per square centimeter. In another example, the contact points may be generally round in shape and have a diameter of about 0.5 to about 1 millimeter. This anode side etched geometry provides good electrical contact to the fuel cell, provides flow passages allowing high swirl for optimum mixing of the fuel gas in combination with low pressure drop, and further provides a stiff, uniform support surface for the fuel cell.

Turning to FIGS. 3 and 4, the second face 20 of the base metal sheet 12, on the side opposite the first face 20, having cathode gas flow passages 22 and standing contact surfaces 18 is shown. Most preferably, the cathode gas flow passages 22 are configured to provide deep flow passages to promote oxidant mixing and a large surface area for optimum heat transfer to the cathode gas stream. In one embodiment, for example, cathode gas flow passages 22 comprise a depth of about 1.0 millimeter. In a preferred embodiment, the cathode gas flow passages 22 have a total surface area for heat transfer of about 2 to about 4 times the projected area of the second face 20. The cathode face 20 also provides good electrical contact and a stiff, uniform structural support for the fuel cell.

One or more optional coating layers may be disposed upon the base metal sheet 12, if desired. Each face 14, 20 may be coated with one or more coatings prior to or subsequent to the etching process, as desired. For example, an optional conductive coating layer or layers may be provided on one

or both faces 14, 20 to enhance electrical conductivity between the interconnect 10 and mating fuel cell surfaces. Further, an optional yielding layer may be disposed on one or both faces 14, 20 to enhance conformity of the interconnect 10 to the surface irregularities in the mating ceramic fuel cell. The optional conductive coating layer may comprise any suitable material providing high-temperature conductivity and chemical compatibility with the fuel cell element. Examples of suitable conductive coatings include, but are not limited to, pure nickel, silver, gold, platinum, conductive glass, intermetallics, and combinations thereof.

In one embodiment of the present invention, an etched interconnect fuel cell stack assembly includes a gas supply comprising external stamped sheet metal manifolds secured to the outside of the fuel cell stack assembly (not shown).

In an alternate embodiment, integral gas supply manifolds 24 are provided to the fuel cell element and interconnects 10. In this embodiment, the interconnects 10 have large through passages 26 arranged along the interconnect outer perimeter 28 to form integral inlet and outlet manifolds when stacked. The interconnects 10 and ceramic fuel cell element are sized and configured so that the gas supply through passages 26 align with matching through holes in the ceramic fuel cell element. The arrangement avoids the need for gaskets between the interconnects. Optionally, the non-active portion of the fuel cell is coated with a glass adhesive to prevent oxidation of the edges of the cell.

In an alternate embodiment, the interconnects 10 are fused to the fuel cell stack. Fusing may be effected, for example, by placing the assembled fuel cell stack assembly in a brazing furnace with the stack under load, thereby flattening and fusing the fuel cells to the interconnects 10. A brazing alloy can be coated onto the interconnect or cell surfaces prior to the fusing process to enhance the bonding between the components. This embodiment is particularly advantageous for providing good gas sealing, and enhanced electrical and heat

conduction. Further, the fusing device provides a strong, robust device for subsequent handling and assembly.

The embodiments of the present interconnect, although particularly advantageous for applications comprising a planar fuel cell element for use in a vehicle, can also be utilized in various other fuel cell configurations. The embodiments can further be used in numerous applications, including, but not limited to, co-generation of heat and electric power, distributed electric power generation such as small scale power plants for commercial/industrial/marine applications, and portable power generation, such as military/construction/recreational applications, among others.

The various embodiments of the present invention provide numerous advantages over the prior art. Some of the advantages of various embodiments of the present etched interconnects include, but are not limited to: (1) ease of manufacture and lower fabrication cost with a minimum number of parts; (2) robust component parts enhancing ease of assembly; (3) large heat transfer surface area; (4) low pressure drops in the fuel and oxidant gas streams; (5) shaped flow passages for generating swirl without excessive turbulence; (6) integral manifolding; (7) good electrical contact; (8) thinner interconnects providing a more compact stack assembly; (9) reduced overall mass and volume of the fuel cell assembly; (10) robust structure as assembled; and (11) enhanced fuel utilization resulting in higher power density.

While the invention has been described by reference to certain preferred embodiments, it should be understood that numerous changes could be made within the spirit and scope of the inventive concepts described. Accordingly, it is intended that the invention not be limited to the disclosed embodiments, but that it have the full scope permitted by the language of the following claims.